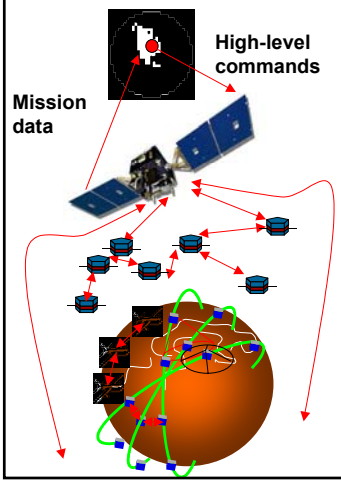
CORNELL UNIVERSITY

Human Centered Control of Complex Automata-Teams



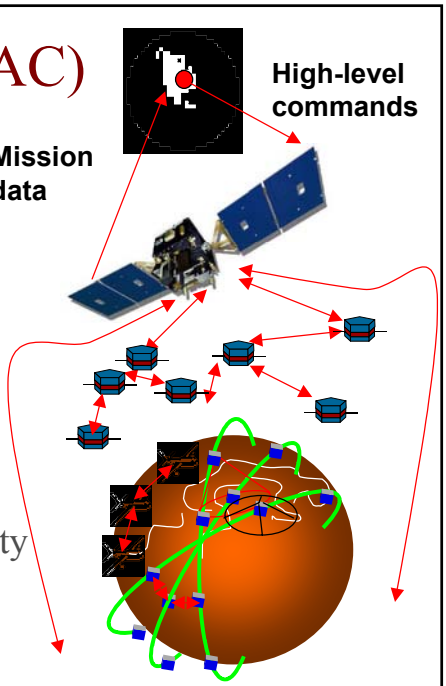
Prof. Mark Campbell

ICASE/USRA/LaRC WORKSHOP ON
REVOLUTIONARY AEROSPACE
SYSTEMS CONCEPTS
FOR HUMAN/ROBOTIC EXPLORATION
OF THE SOLAR SYSTEM

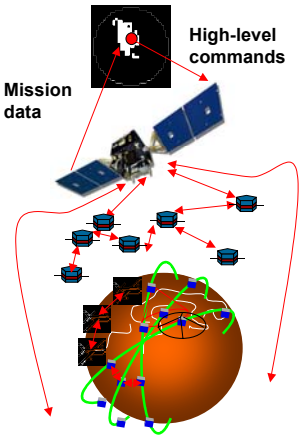
Nov 6-7, 2001

Future Concept (NIAC)

- Missions composed of many resources
  - Science instruments
  - Rovers, UAV's
  - Satellites (mother, GPS)
  - Self developing systems
  - Humans?
- Advantages
  - Redundancy, Adaptability
- Disadvantages
  - Science fusion, cost



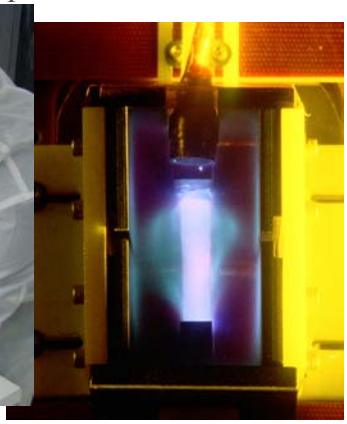
Future Concept (NIAC)



- Required technologies
  - Miniaturized components (MEMS)
  - Low mass platforms
  - Self consuming systems
  - Self designing systems
  - Coordinated autonomy of complex systems with many platforms
  - Autonomy with humans "in the loop"

Low Mass Platforms

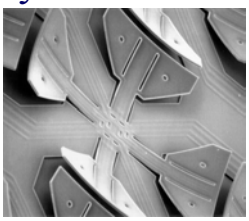
- 15kg, fully functional, student built satellite
  - Electric propulsion, comm, GPS, x-link, 4 cameras
  - NIAC study: factor of 4 mass improvement with MEMS

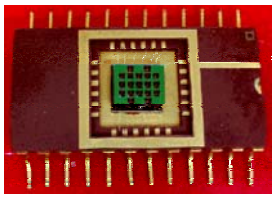


MEMS Components

- MEMS based components can drastically reduce mass in *all* subsystems

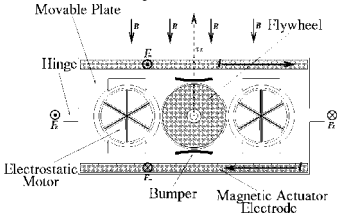
Docking "fingers"



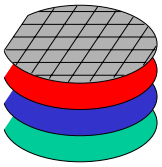


Propulsion chip (Lewis *et al*)

Control Moment Gyro



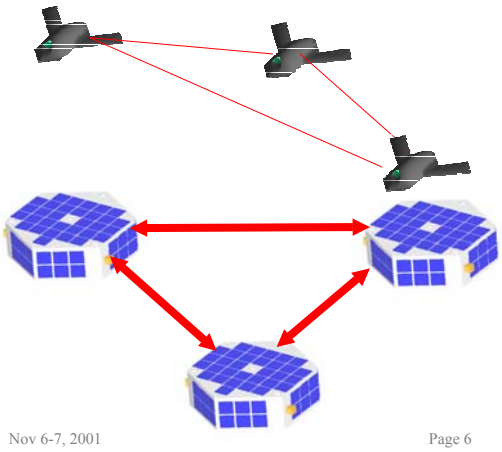
MEMS based satellite



- Solar cells/thin film batteries
- Microelectronics
- Micro-gyros
- Micro-CMG's

Coordinated Control

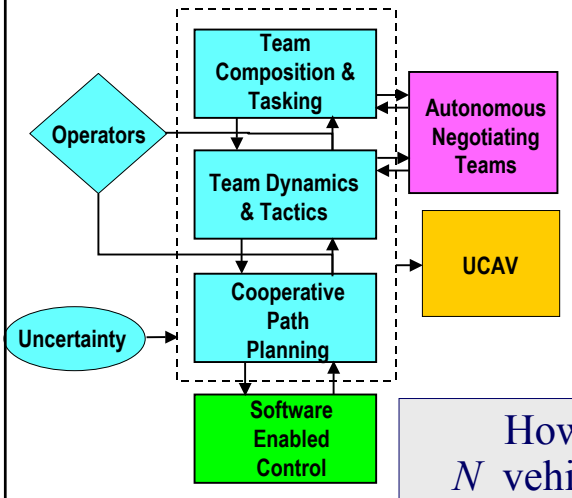
- Formation flying, planning
  - Sensing, propulsion, coordination/autonomy

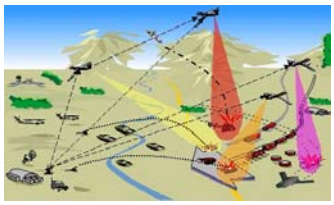


Autonomous Systems with Humans

- If human is on Earth, the complex system must
  - Be able to explore uncertain environment
  - Overcome latency
- If human is with the system, the complex system must be designed to
  - Remove human from low level tasks (i.e. simply directing science
  - Be simple to use
- In both cases, humans must "interface" with complex autonomous system

Mixed Initiative Control of Automa-teams (DARPA MICA)

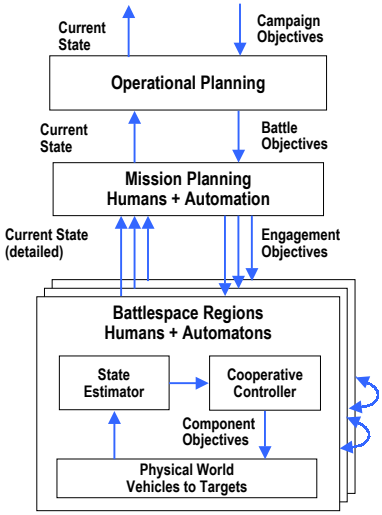




How can we achieve
N vehicles >> M operators?

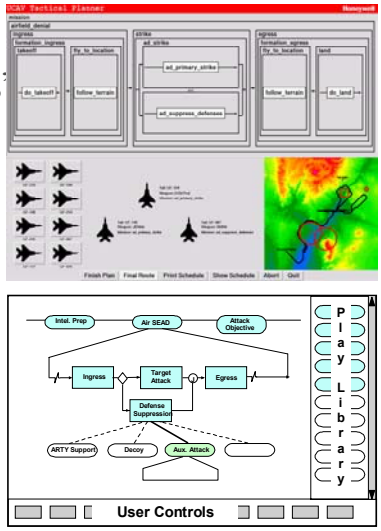
MICA Hierarchy

- Develop theory, algorithms, software, and modeling/simulation capabilities for hierarchical battlespace management and distributed control of semi-autonomous entities
- Important technologies
  - Humans factors
  - Coordinated control
  - Sensor fusion/estimation



Human/System Interface Design (physical/information)

- Efficient human interactions
  - Efficient "distilled commands"
  - Use past information
  - human "intuitive" commands
  - Task-centric commands ("natural")
- Example: Playbook
  - operator acts as a "quarterback"

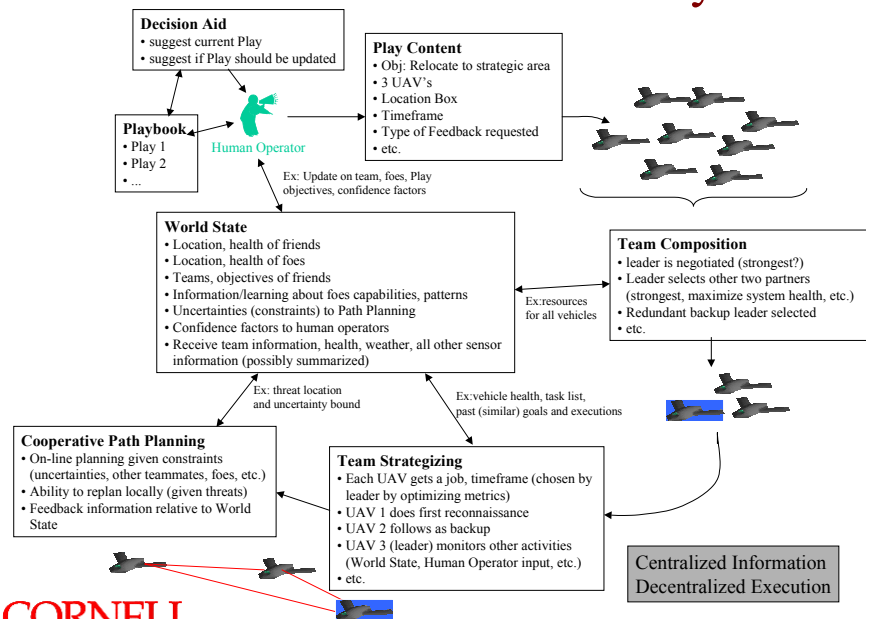


Determine Appropriate Automation Level

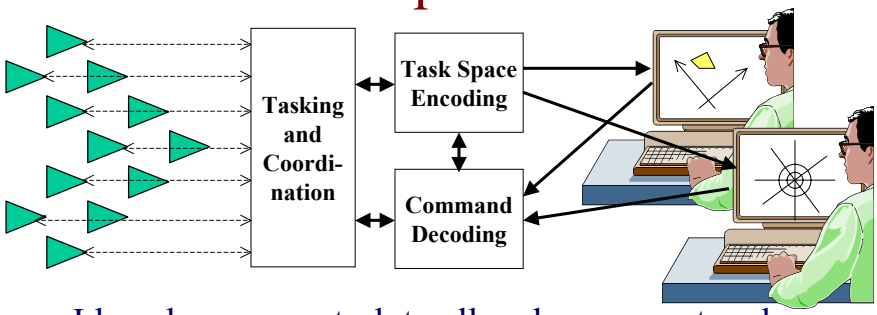
Degrees of Automation	Mixed Initiative Control Example
Human does it all	Decides next targets
Computer offers alternatives	Strategic list of targets, teams
Narrows alternatives to a few	List of targets, teams and probability of success
Suggests an alternative	Target, teams
Computer executes if human approves	Weapons deployment
Computer executes, human can veto	Weapons deployment
Computer executes, informs human	Vehicle maneuver
Informs human only if asked	Vehicle sensing/tracking
Informs human only if it decides to	Minor internal faults
Computer acts autonomously	Rudder command

For each function, where is the functional limit?

Mixed Initiative Control: Playbook



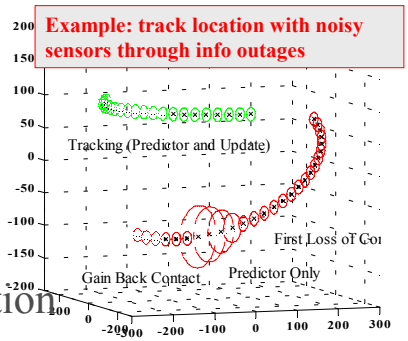
Mixed Initiative Control: *N* on *M* Task Space Control



- Idea: decompose task to allow human centered control with $M = N$
- Example: position/shape decomposition
  - Control shape separately from formation location
  - Present different views that enable task coordination

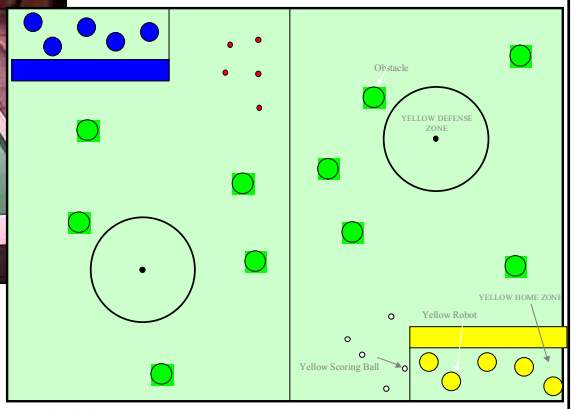
Sensor Fusion

- Examples
  - Location, health
  - Information/learning about environment
  - Latency in communication
  - Uncertainties (constraints) to Planning
  - Confidence factors to human operators
  - Team information, health, weather



Testbed: Capture the Flag using Robots

R. D'Andrea, Cornell



Important conclusion: fully autonomous systems perform soccer better *without* humans in the loop

Conclusions

- Future technology (MEMS, autonomy) will enable complex, multi-vehicle systems for exploration
- Humans must interface with autonomous systems whether they are on Earth or not
- Hierarchical autonomy is an excellent approach to integrating humans in the loop
- Other programs (such as DARPA MICA) should be leveraged